圖訊識別
Pattern Recognition

Spring 2026

吳俊霖
Jiunn-Lin Wu
jlwu@cs.nchu.edu.tw

國立中興大學

Textbook, Reference and Lecture Notes

- Textbook:
  - "Pattern Classification", by Richard O. Duda, Peter E. Hart and David G. Stork, John Wiley & Sons, 2nd edition, 2001(歐亞)
- References:
  - "Introduction to Statistical Pattern Recognition" by Keinosuke Fukunaga, Academic Press, 2nd edition,1990.
  - "Neural Networks and Learning Machines" by Simon O. Haykin, Pearson Education, Inc., 3rd Edition, 2009.
  - "Artificial Intelligence" by Leonardo Araujo dos Santos, 2018.
  - Fundamentals of Machine Learning for Predictive Data Anayltics: Algorithms, Worked Examples, and Case Studies, J.D. Kelleher, B.M. Namee, A. D'Arcy, 2nd Edition, 2020.
- Lecture Notes:
  - Available before the day of class.
  - http://web.nchu.edu.tw/~jlwu

Definition

- Pattern recognition is the study of how machines can
  - observe the environment,
  - learn to distinguish patterns of interest,
  - make decisions about the categories of the patterns.

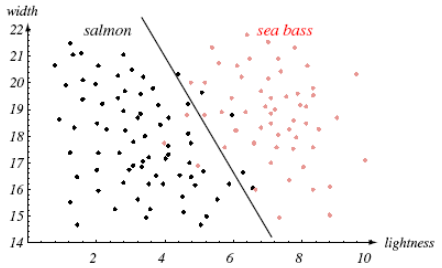
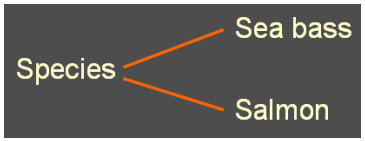
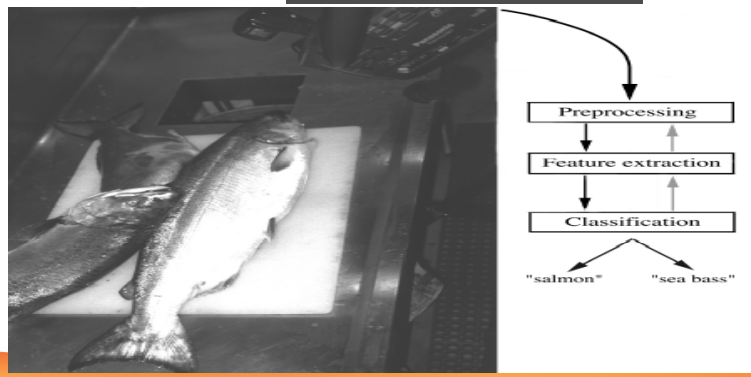


FIGURE 1.4. The two features of lightness and width for sea bass and salmon. The dark line could serve as a decision boundary of our classifier. Overall classification error on the data shown is lower than if we use only one feature as in Fig. 1.3, but there will still be some errors. From: Richard O. Duda, Peter E. Hart, and David G. Stork, *Pattern Classification*. Copyright © 2001 by John Wiley & Sons, Inc.

Pattern Recognition

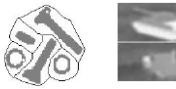
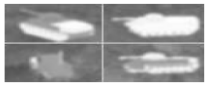
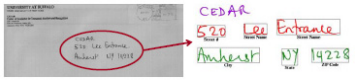
- Sorting incoming Fish on a conveyor according to species using optical sensing.

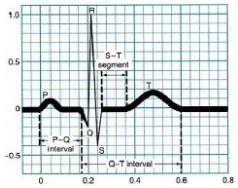


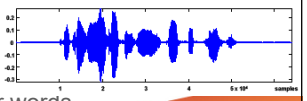


Examples of PR Problems

- Machine vision
  - Visual inspection, ATR
  - Imaging device detects ground target
  - Classification into “friend” or “foe”
- Character recognition
  - Automated mail sorting, processing bank checks
  - Scanner captures an image of the text
  - Image is converted into constituent characters
- Computer aided diagnosis
  - Medical imaging, EEG, ECG signal analysis
  - Designed to assist (not replace) physicians
- Speech recognition
  - Speech recognition / speaker identification
  - Microphone records acoustic signal
  - Speech signal is classified into phonemes and/or words



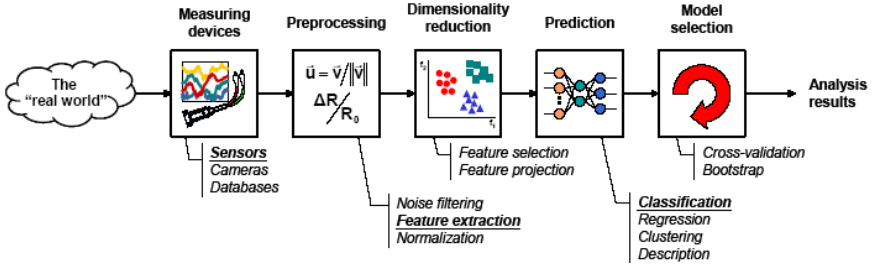


What is a Pattern?

- Watanabe defines a pattern “as opposite of chaos; it is an entity, vaguely defined, that could be given a name”.
- Examples:
  - fingerprint,
  - handwritten cursive word,
  - a human face,
  - a speech signal...

Components of a Pattern Recognition System

- A basic pattern classification system contains
  - A sensor
  - A preprocessing mechanism
  - A feature extraction mechanism (manual or automated)
  - A classification algorithm
  - A set of examples (training set) already classified or described

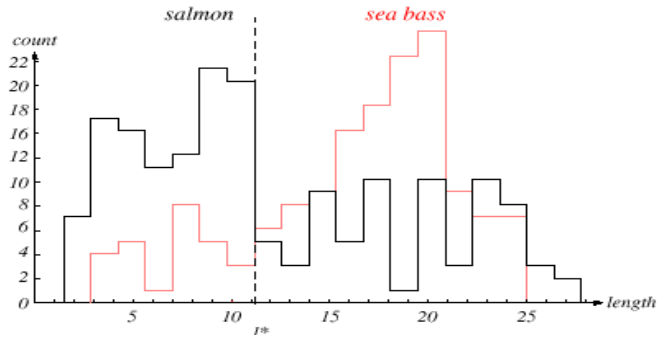


Problem Analysis

- Feature is any distinctive aspect, quality or characteristic.
  - Features may be symbolic (i.e., color) or numeric (i.e., height)
  - In the problem of fish classification, the *features* include: length, lightness, width, number and shape of fins, position of the mouth, etc…
- The number of the features
- The number of the training samples
- Feature Selection
- Feature Extraction

Classification

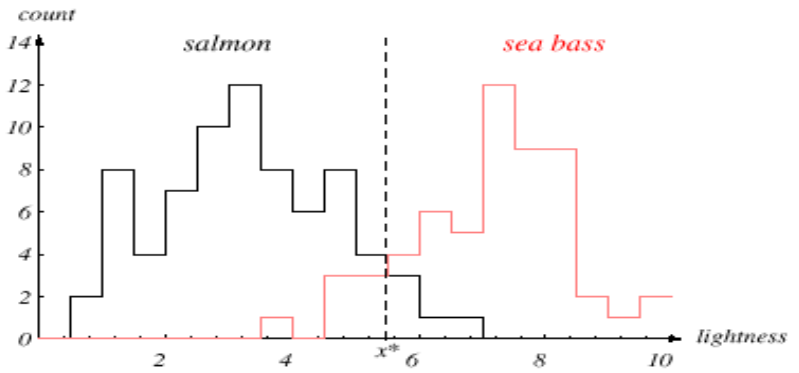
- Select the length of the fish as a possible feature for discrimination.



- The value marked l* will lead to the smallest number of errors, on average.

Classification

- The length is a poor feature alone!
- Select the lightness as a possible feature.



Two Features

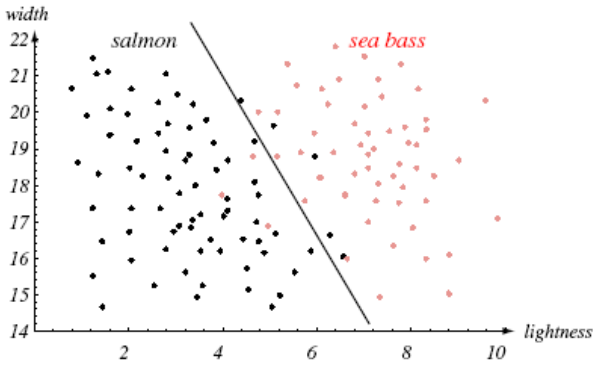


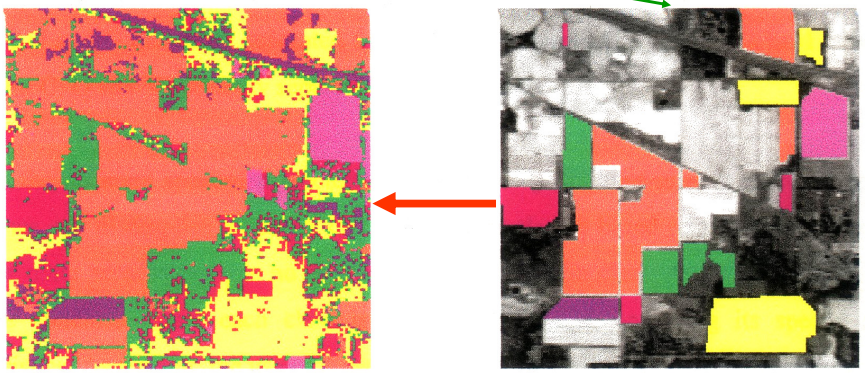
FIGURE 1.4. The two features of lightness and width for sea bass and salmon. The dark line could serve as a decision boundary of our classifier. Overall classification error on the data shown is lower than if we use only one feature as in Fig. 1.3, but there will still be some errors. From: Richard O. Duda, Peter E. Hart, and David G. Stork, *Pattern Classification*. Copyright © 2001 by John Wiley & Sons, Inc.

Types of Recognition

- **Supervised classification**:
  - Input pattern is identified as a member of a pre-defined class.
  - Patterns whose class is known a-priori are used for training.
- **Unsupervised classification**:
  - Input pattern is assigned to a hitherto unknown class.
  - The number of classes is (in general) unknown and no training patterns are available.

Supervised Classification

- Remote Sensing with the ground-truth data



Classified Image

Comparable ROIs

Unsupervised Classification

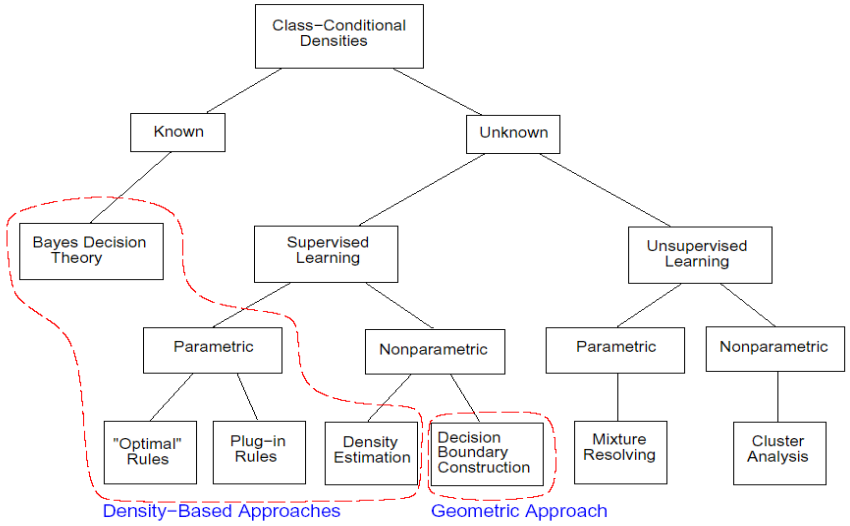
- Image Segmentation

- Data Mining

Types of Recognition

- **Parametric classification:** Assume we have a density function that can be characterized by a set of parameters, we can design a classifier using estimates of the parameters.
  - Hypothesis testing
  - Bayes classifier
- **Nonparametric classification**: We somehow have to estimates the density functions using an unstructured approach. *The estimates is far less reliable with larger bias and variance than the parametric counterpart.*
  - Statistical approaches - kNN
  - Neural networks

Various Approaches in Statistical PR



Pattern Recognition Methods

- Template matching
  - A template (typically a 2D shape) or a prototype of the pattern to be recognized is available.
  - Compute the similarity between the template and the pattern to be matched.
  - Take into account pose (rotation, translation) and scale changes.
- Statistical approach
  - Each pattern is represented in terms of *d* features, and is viewed as a point in a *d*-dimensional space
  - The goal is to choose those features that allow pattern vectors belonging to different categories to occupy compact and disjoint regions in a *d*-dimensional feature space.

Pattern Recognition Methods

- Syntactic approach
  - Use hierarchical structures to represent complex patterns.
  - The simplest unit is called: primitives
  - Complex pattern is represented in terms of the interrelationships (grammars) between the primitives.
  - Grammatical rules can be learned by training.
- Neural networks (Machine Learning)
  - Massively parallel computing systems consisting of an extremely large number of simple processors with many interconnections.
  - Can learn complex non-linear input-output relationships.
  - Feed-forward networks such as multilayer perceptron and Radial Basis Function network are useful for pattern classification.

Syntactic Approach

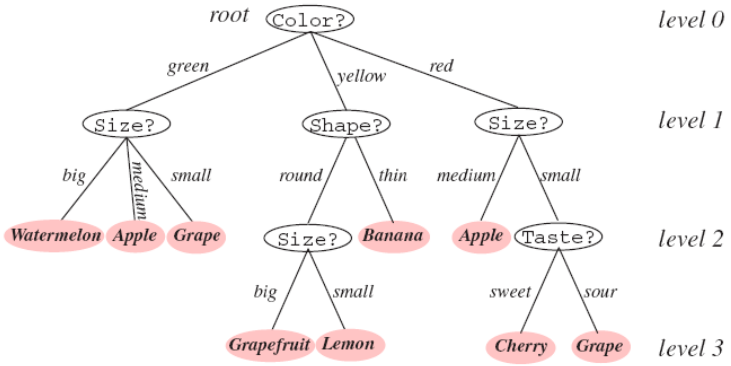


FIGURE 8.1. Classification in a basic decision tree proceeds from top to bottom. The questions asked at each node concern a particular property of the pattern, and the downward links correspond to the possible values. Successive nodes are visited until a terminal or leaf node is reached, where the category label is read. Note that the same question, `Size?`, appears in different places in the tree and that different questions can have different numbers of branches. Moreover, different leaf nodes, shown in pink, can be labeled by the same category (e.g., **Apple**). From: Richard O. Duda, Peter E. Hart, and David G. Stork, *Pattern Classification*. Copyright © 2001 by John Wiley & Sons, Inc.

Example: Neural, Statistical and Structural OCR

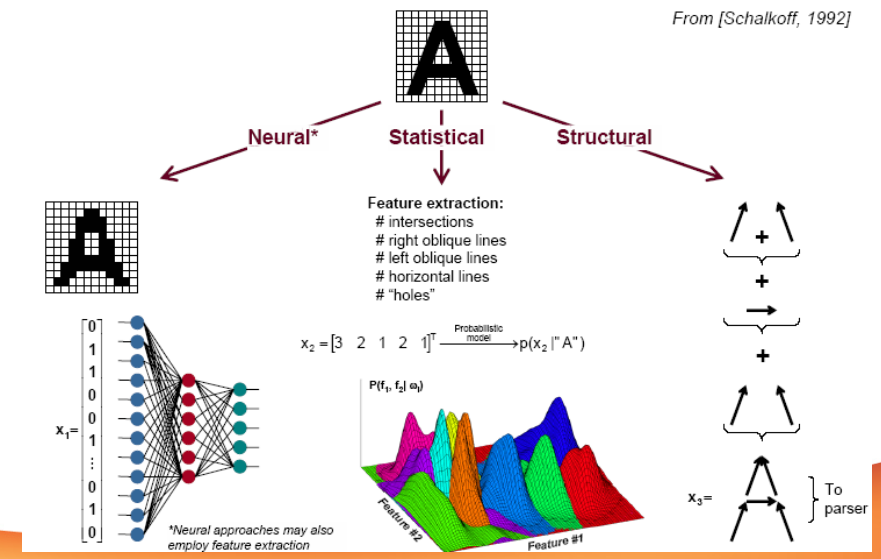
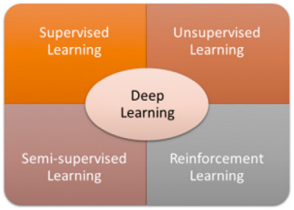
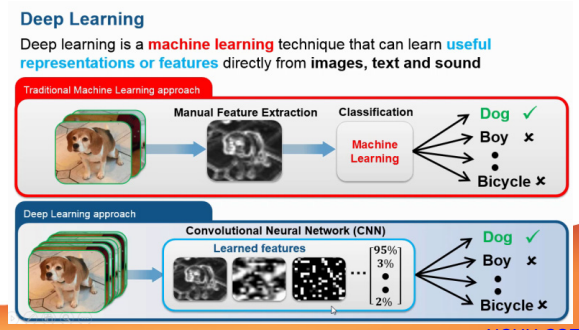


Image Classification / Recognition

- Deep learning is a branch of machine learning based on a set of algorithms that learn to represent the data.
- Deep convolutional neural networks accept image as inputs and are ideally suited for automatic learning and image classification.





Deep Convolutional Neural Networks

- The deep neural network is an emerging machine learning method that has proven its potential for different classification tasks.
- Notably, the convolutional neural network dominates with the best results on varying image classification tasks.
- Transfer learning is a machine learning method where a model developed for a task is reused as the starting point for a model on a second task.
- The intuition behind transfer learning for image classification is that if a model is trained on a large and general enough dataset, this model will effectively serve as a generic model of the visual world.
- You can then take advantage of these learned feature maps without having to start from scratch by training a large model on a large dataset.

Feature Extraction and Linear Mapping

- Feature Extraction and Linear Mapping for Signal Representation
  - Feature selection for signal representation has wide applications in some areas such as data compression in communication systems .
  - Principle Component Analysis
- Feature Extraction and Linear Mapping for Classification
  - The selection of the features is important and strongly affects classifier design.
  - Optimum Linear Transformation
- Feature Extraction using Deep Learning - Autoencoder

Difference between Signal Representation and Classification

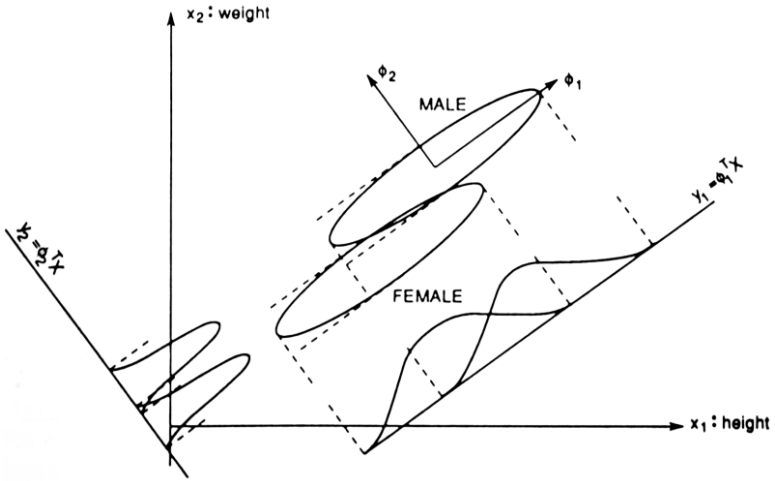


Fig. 10-1 An example of feature extraction for classification.

Course Outline

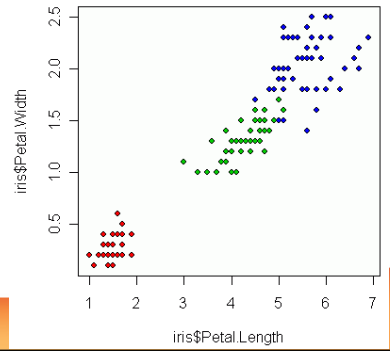
- Introduction
- Bayes Decision Theory
  - Maximum-Likelihood and Bayesian Parameter Estimation
  - Linear Discriminant Functions
- Nonparametric Techniques
  - K Nearest Neighbors algorithm
- Multilayer Neural Networks
  - Backpropagation Network
  - Support Vector Machines
- Deep Learning
  - Convolutional Neural Networks
  - Transfer Learning

Course Outline

- Unsupervised Learning and Clustering
  - K- Means (Statistical approach)
  - Self-Organizing Feature Map (Neural Networks)
- Feature Extraction and Linear Mapping
  - for Signal Representation - Principle Component Analysis
  - for Classification - Optimum Linear Transformation
- Feature Extraction Using Deep Learning
  - Autoencoder
  - Pre-Trained Model (Transfer Learning)
- Ensemble learning
  - It uses multiple learning algorithms to obtain better predictive performance than could be obtained from any of the constituent learning algorithms alone.

Dataset - IRIS

- Iris 資料集是在圖型識別領域中，最常被引用到的資料集之一，此資料集包含鳶尾花的資料，特性如下：
  - 共有三種鳶尾花的品種(Iris Setosa, Iris Versicolour, Iris Virginica)
  - 共有四個數值特徵值: 鳶尾花的「萼片長」、「萼片寬」、「花瓣長」、「花瓣寬」
  - 資料共有150筆。(每個類別各50筆)



Dataset - WINE

- UCI Machine Learning Repository
- Abstract: Using chemical analysis determine the origin of wines
- Data Set Information: These data are the results of a chemical analysis of wines grown in the same region in Italy but derived from three different cultivars. The analysis determined the quantities of 13 constituents found in each of the three types of wines.

Data Set Characteristics:	Multivariate	**Number of Instances:**	178	**Area:**	Physical
Attribute Characteristics:	Integer, Real	**Number of Attributes:**	13	**Date Donated**	1991-07-01
Associated Tasks:	Classification	**Missing Values?**	No	**Number of Web Hits:**	835034

Patten Recognition - Classifier

- Supervised Classification
  - Statistical approach
    - Maximum-Likelihood Classifier (Bayes Decision Theory)
    - Fisher Linear Discriminant Analysis
    - K Nearest Neighbors Classifier
  - Neural Networks
    - Back-Propagation Neural Networks
    - Support Vector Machines
    - Deep Learning (Convolutional Neural Networks)
- Unsupervised Classification
  - Statistical approach
    - K- Means
  - Neural Networks
    - Self-Organizing Feature Map

Patten Recognition – Feature Extraction

- Signal Processing Approaches
  - Signal Representation - Principle Component Analysis
  - Classification - Optimum Linear Transformation
- Deep Learning Approaches
  - Autoencoder
  - Pre-Trained Model (Transfer Learning)

Grading

- Homework 40%
- Final Exam 40%
- Final Project 20%